Implementation of an AGS-COSMOS-FHWA Compatible Geotechnical Database for the St. Louis Metro Area, Missouri and Illinois and, the Evansville-Henderson Area, Indiana and Kentucky

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Final Technical Report

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ABSTRACT

The St. Louis metropolitan area is the major urban region of the USGS Earthquake Hazard Program's plan for assessing and reducing the hazard risks of an earthquake likely emanating from New Madrid Seismic Zone. The St. Louis metropolitan area consists of counties in both Missouri and Illinois, which are split by Mississippi River. Both Missouri and Illinois have state geological surveys that have produced their own geological maps and datasets, employing dissimilar geodata information and systems such as mapping units, mapping scales, and storage formats. It is currently necessary to combine these dissimilar geodata from both states' geological surveys and integrate them into a single GIS layer, which can be input into any kind of quick spatial analysis and reconnaissance, can be accessible to researchers, and will allow them to standardize geologic interpretations. The existing geodata of surficial geology, loess thickness, bedrock geology, well locations, and measured values and locations of shear wave velocity (Vs) within the St. Louis metropolitan, Missouri and Illinois, were collected to be integrated into a single GIS layer.

1. INTRODUCTION

The St. Louis metropolitan area (STL) is the major urban region of the US Geological Survey (USGS) Earthquake Hazard Program's (EHP) plan for the central and eastern United States. The St. Louis metropolitan area is split between Missouri and Illinois. Both Missouri and Illinois have state geological surveys that have separately investigated and produced their own geological maps and datasets. As a result, each geological survey employs dissimilar geodata information and systems such as mapping units, mapping scales, and storage formats of hardcopy or digital data. It is currently necessary to combine these dissimilar geodata from Missouri and Illinois geological surveys and integrate them into a single layer. The objectives of this project are to collect geodata from Missouri and Illinois states geological surveys and private agency for the St. Louis metropolitan and convert these into ArcGIS format. These geodata include 1) surficial geology, 2) loess thickness, 3) bedrock geology, 4) well locations, and 5) the measured values and locations of shear wave velocity (Vs). This research mainly employed the Universal Transverse Mercator (UTM) grid coordinates. The UTM Zone 15 covers the Missouri and the western Illinois side within STL, whereas eastern Illinois lies in the UTM Zone 16.

2. STUDY AREA

The study area encompasses 29 USGS quadrangles (7.5-minute) in the St. Louis metropolitan area across both Missouri and Illinois with a land area of 4,432 km^2 (Fig. 1). The St. Louis metropolitan area includes the confluence regions of the Missouri, Illinois, and Meramec rivers with Mississippi River, and is situated on low-lying alluvial floodplains along these four major rivers and the high-standing loessal uplands on both sides. The southern part of STL is about 200 km north of the New Madrid Seismic Zone (NMSZ), which produced several very large earthquakes in historic (in 1811 and 1812 or earlier) and geologic time.

3. GEODATA COMPILATION

3.1. SURFICIAL GEOLOGIC MAP

Surficial geologic maps were compiled from the publications of the Missouri Department of Natural Resources' Division of Geology and Land Survey (MoDNR-DGLS), the Illinois State Geological Survey (ISGS), and the U.S. Geological Survey (USGS). Schultz compiled existing data of 1) the City of St. Louis and St. Louis County (Goodfield, 1965), 2) St. Charles County (Allen and Ward, 1977), and 3) eastern St. Louis, Illinois side (Lineback, 1979), and produced the geologic map of St. Louis 30'×60' quadrangle (1:100,000 scale). The Missouri portion of Schultz's map was manually digitized and the descriptions of geologic units were input into attribute tables for a geographic information systems (GIS) format. The Illinois portion of the study area was mapped at 1:24,000 to 1:100,000 scale by the ISGS and the corresponding GIS format was provided by Grimley (2007, personal communication). The surficial geology of Jefferson County, Missouri, has not been mapped and thus remains unmapped in this work. The 17 data sources of St. Louis metropolitan area are shown in Figure 2. Stratigraphic units and correlation, recognized in Missouri and Illinois, by Schultz (1997) and ISGS, are presented in Table 1.

A prominent problem in generating a single Quaternary geologic map of the St. Louis metropolitan area by compiling data from various origins has been the disparity of mapping unit and scales between Missouri and Illinois. Missouri has traditionally employed depositional environment mapping at scales above 1:62,500 to compile their geologic maps. Illinois has named formational mapping of units by correlating stratigraphy, as well as by interpreting depositional environment. The ISGS Metro-East mapping project funded by USGS STATEMAP program recently completed 7.5' (1:24,000 scale) quadrangle maps of the eastern St. Louis metropolitan area. The disparity of mapping units and scales indicates that Missouri does not have the same level of detail as that available on the Illinois side, so uncertainties in stratigraphy will be more pronounced on the Missouri side, where many data gaps presently exist.

3.2. LOESS THICKNESS MAP

The data sources of loess thickness include the publications of Goodfield (1965) for the City of St. Louis and St. Louis County, Thorp and Smith (1952) for St. Charles and Jefferson counties, and the Illinois State Geological Survey (ISGS) for Illinois portion. The Missouri portion mapped by Goodfield (1965) and Thorp and Smith (1952) were manually digitized and the values of loess thickness (in feet) were input into an attribute table for a GIS format. The Illinois portion was mapped by the ISGS and the corresponding GIS shapefile was provided by Grimley (2007, personal communication). The five data sources for total loess thickness (combination of Peoria loess and Roxana units in feet) are shown in Figure 3.

The Illinois portion was mapped ranging from a scale of 1:24,000 to 1:100,000 and the City of St. Louis and St. Louis County at a scale of approximately 1:65,000, whereas St. Charles and Jefferson counties in Missouri were mapped at the considerably smaller scale of 1:2,500,000 by Thorp and Smith (1952). Therefore, these two county areas of Missouri do not have the same level of detail available as that of the remaining area of St. Louis metropolitan area mapped by Goodfield (1965) or ISGS. Therefore uncertainties in the loess thickness will be more prominent in the areas of St. Charles and Jefferson counties, where the contour lines were mapped in much less detail.

3.3. BEDROCK GEOLOGY

Geologic maps were collected from the publications of MoDNR-DGLS, the ISGS, and USGS. The maps (1:24,000 scale) of the House, Maxville, and Oakville quadrangles in Missouri were manually digitized and the descriptions of geologic units were input into attribute tables. The bedrock geology of St. Louis 30'×60' quadrangle (1:100,000 scale) was compiled by Harrison (1997) and the corresponding GIS shapefile was provided by Harrison (2006, personal communication). This map was used for the Missouri portion. The statewide map (1:500,000 scale) of Illinois was published by Kolata (2005) and the Illinois portion of the study area was provided with a GIS shapefile from ISGS (2007, personal communication).

These five digitized maps consisting of three 7.5' quadrangles in Missouri, Shultz (1997), and Kolata (2005) showing the bedrock geology of St. Louis metropolitan area were compiled and integrated into one GIS shapefile. The index map shows the map area of the five data source for compiled bedrock geology map (Fig. 4).

A prominent problem in joining bedrock geologic maps of the St. Louis metropolitan area has been the disparity of the different scales between three 1:24,000 scale quadrangles in southern St. Louis metropolitan area, Missouri and a 1:100,000 scale St. Louis quadrangle for Missouri portion. The disparity of the different scaled maps caused the mismatched map boundaries. The map symbols and unit correlation are shown in Table 2.

3.4. BOREHOLE INFORMATION

MoDNR-DGLS collected and edited geotechnical boring records for the Missouri portion of the St. Louis metropolitan area in order to create the database of St. Louis surficial materials funded under the U.S Geological Survey -National Earthquake Hazard Reduction Program. Most geotechnical borings drilled by the Missouri Department of Transportation were taken for highway and bridge construction. Boring locations in the Missouri portion are in UTM zone 15, North American Datum (NAD) 1983 coordinates. The data source is identified by project and boring number convention for more detailed information (Palmer, 2006).

ISGS has collected and maintained the boreholes drilled in the state of Illinois under regulatory programs of the state. The data contain 1) all borings and water wells issued by the Illinois Department of Mines and Minerals and by the Illinois Department of Public Health and county health departments, and 2) some engineering borings submitted by the Illinois Department of Transportation (IDOT) and other private agencies. Each borehole has a unique identifier numbered as American Petroleum Institute (API) code. The data points in Illinois were originally referenced with the geographic coordinate system (latitude/longitude) and these points were converted to UTM coordinates (zone 15 and 16) in this work.

The existing database of borehole information for Missouri and Illinois portions were provided from the Missouri and Illinois geological surveys (MoDNR-DGLS and ISGS) in Microsoft Access 97 and spreadsheet format, respectively.

The borehole records are available for 2,394 sites for Missouri portion and 4,817 sites for Illinois portion. The borehole sites of both Missouri and Illinois generally have multiple types of boring records. Table 3 shows the type (originally classified by MoDNR-DGLS and ISGS) and number of borehole records. The GIS map (Fig. 5) presents borings locations and types of the St. Louis metropolitan area, plotted in UTM coordinates (zone 15 and 16).

3.5. SHEAR WAVE VELOCITIES AND SESMIC GROUND AMPLICATION

A total of 117 shear wave velocity (V_S) profiles were measured and provided by the University of Missouri-Rolla (UMR), USGS, and ISGS. The V_S locations and sources were plotted using GIS (Fig. 6). Values of V_S in the upper 30m (V_S^{30}) of corresponding surficial geologic units are summarized in Table 3. For those profiles not extending to 30m, the velocity from 20m to 30m was assumed to be constant (Hoffman 2007, personal communication). The value of V_S^{30} in a single geologic unit is highly variable. This can be attributed to the varieties of grain size distribution, density, compaction, and thickness of the sediment from location to location (Bauer et al., 2001).

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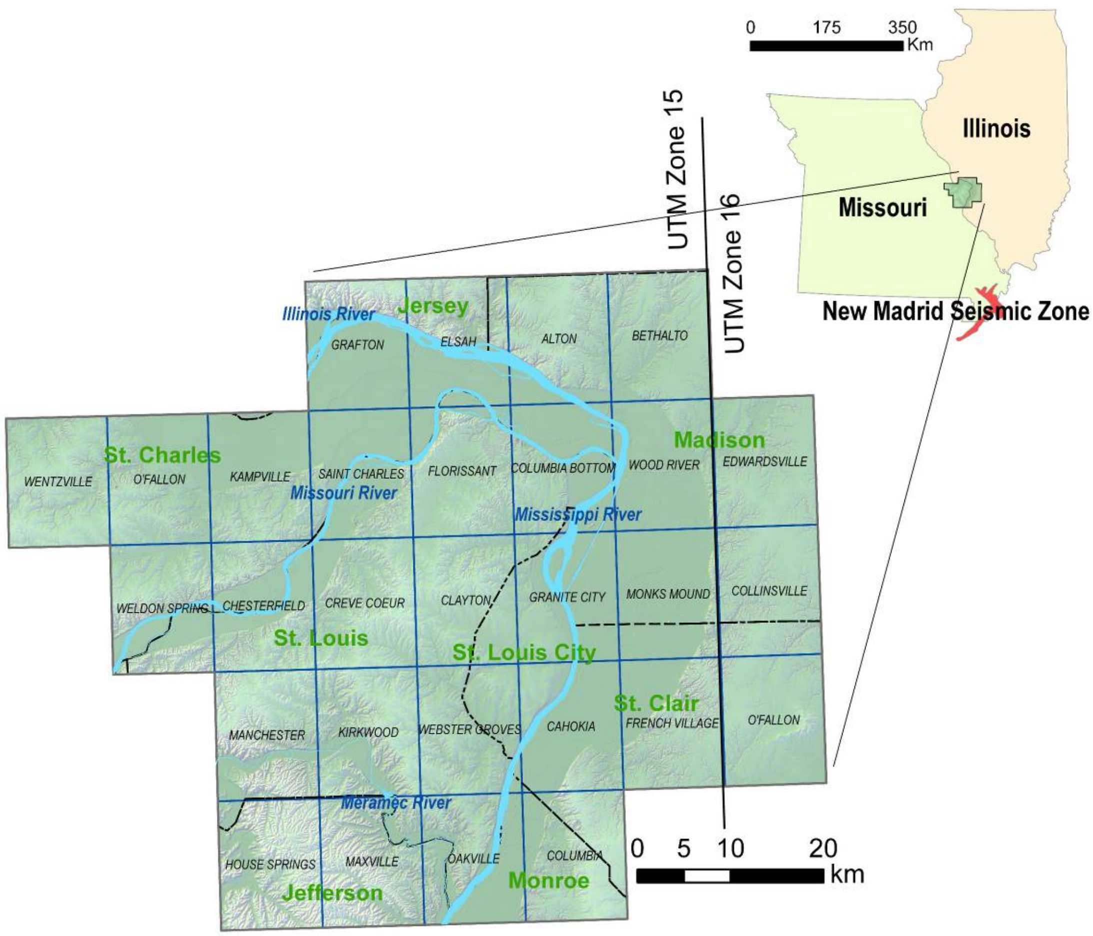
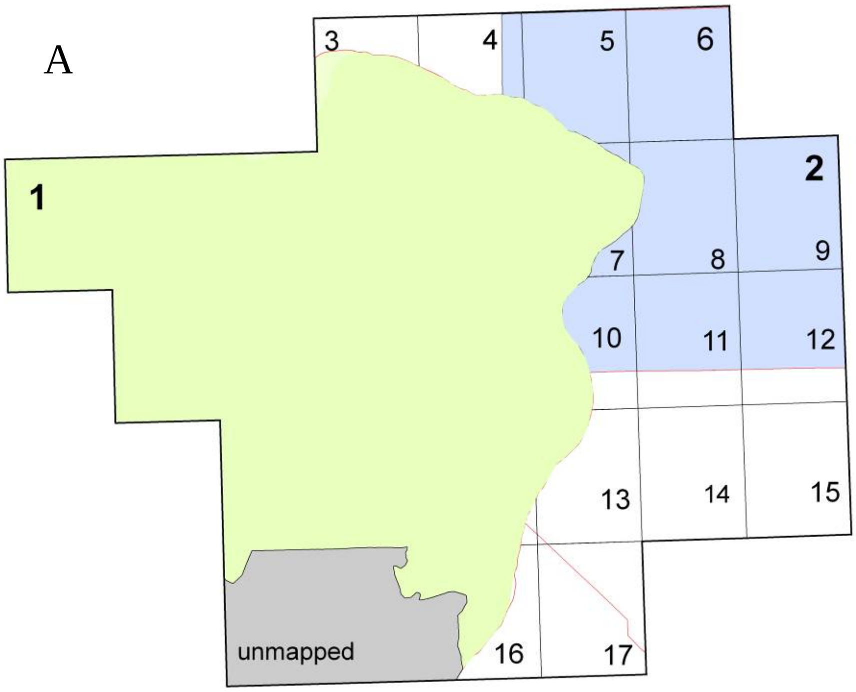


Figure 1. The study area of St. Louis metropolitan area, Missouri and Illinois consisting of 29 USGS quadrangles, which are georeferenced to Universal Transverse Mercator (UTM) Zones 15 and 16. The southern St. Louis metropolitan area is about 200 km from New Madrid Seismic Zone (NMSZ) in the upper Mississippi embayment.



1 Schultz (1993) 1:100,000 2 Grimley and Phillps (2006) 1:100,000
3 Grimley and McKay (1999) 1:24,000 4 Grimley (2002) 1:24,000
5 Grimley (1999) 1:24,000 6 Grimley (2005) 1:24,000
7 Unknown 1:24,000 8 Grimley and Lepley (2005) 1:24,000
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13 Unknown. 1:24,000 14 Grimley (2004) 1:24,000
15 Grimley (1998) 1:24,000 16 Devera (2003) 1:24,000
17 Grimley (2000) 1:24,000

Figure 2. Data sources (17) for surficial geologic map of the St. Louis metropolitan area.

Table 1. Correlation of recognized surficial geologic units and map symbols in the St. Louis metropolitan area, Missouri and Illinois.

Time Scale	Interpretation	This study	Missouri (Schultz, 1993)		Illinois (ISGS publications)	
		Symbol	Symbol	Unit	Symbol	Unit
Holocene (post-glacial)	Man-made fill or cut	**af(dg)**	af	Artificial fill	dg	Disturbe Ground
	Residuum	**R**	R	Residuum		
	Alluvium	**Qa or c**	Qa	Alluvium	c	Cahokia Fm
	Alluvial or colluvial fans	**c(f)**	Qa	Alluvium	c(f)	Cahokia- Fan
	Alluvium (backswamp, channel-fill or overbank)	**c(c)**	Qa	Alluvium	c(c)	Cahokia- Clayey
	Alluvium (point bar or channel)	**c(s)**	Qa	Alluvium	c(s)	Cahokia- Sandy
	Colluvium	**Qp(py)**	Qp	Peyton	py	Peyton Fm
Holocene over Pleistocene	Alluvium over lake deposits	**c/e**			c/e	Cahokia Fm over Equality Fm
	Alluvium (clayey) or lake deposits	**c(c)-e**			c(c)-e	Cahokia- Clayey or Equality Fm
Pleistocene (Wisconsinan)	Lake sediment (slackwater)	**Qtd or e**	Qtd	Terrace deposits	e	Equality Fm
	Outwash	**h**			h	Henry Fm
	Loess	**Ql(pr)**	Ql	Loess	pr	Peoria and Roxana Silts (pr)
Pleistocene (Wisconsinan over Illinoian)	Loess over ice-contact drift	**Ql(pr/pl-h)**			pr/pl-h	(pr) over Pearl Fm-Hagarstown M

	Loess over outwash	**Ql(pr/pl)**			pr/pl	(pr) over Pearl Fm
	Loess over till over lake sediment	**Ql(pr/pb)**			pr/pb	(pr) over Glasford Fm-Petersburg Silt
Pleistocene (Illinoian)	Lake sediment	**Qtd or tr**	Qtd	Terrace deposits	tr	Teneriffe Silt
	Till and ice marginal sediment	**Qt or g**	Qt	Till	g	Glasford Fm
Pre-Illinoian (Kansan)	Till	**Qt**				
Paleozoic	Bedrock	**K**	K	Karst		
		B	B	Bedrock	R	

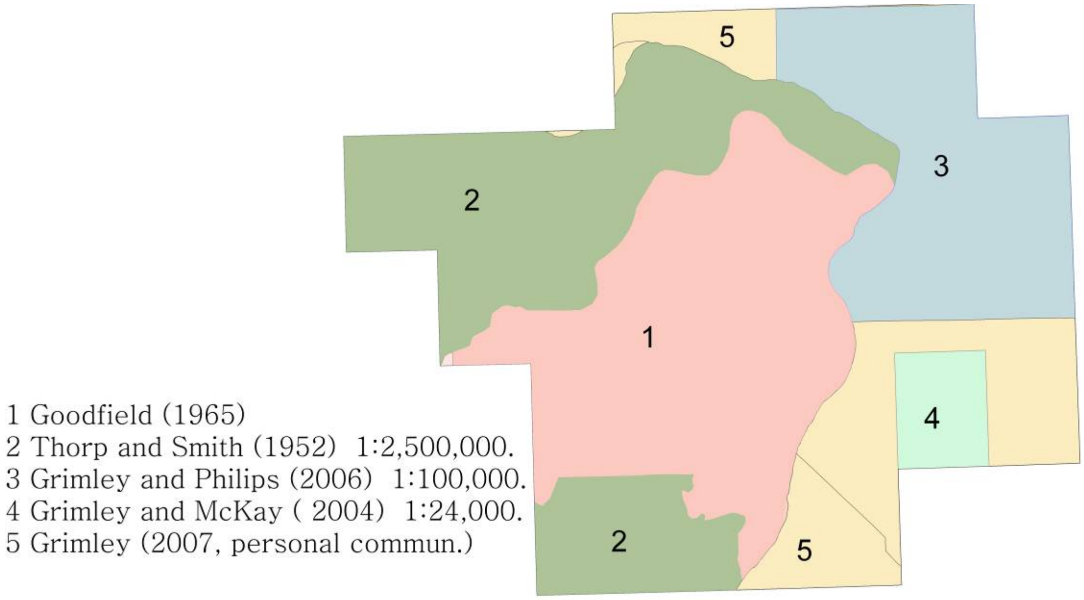

Figure 3. Data sources (5) for loess thickness map of the St. Louis metropolitan area in a GIS vector format.

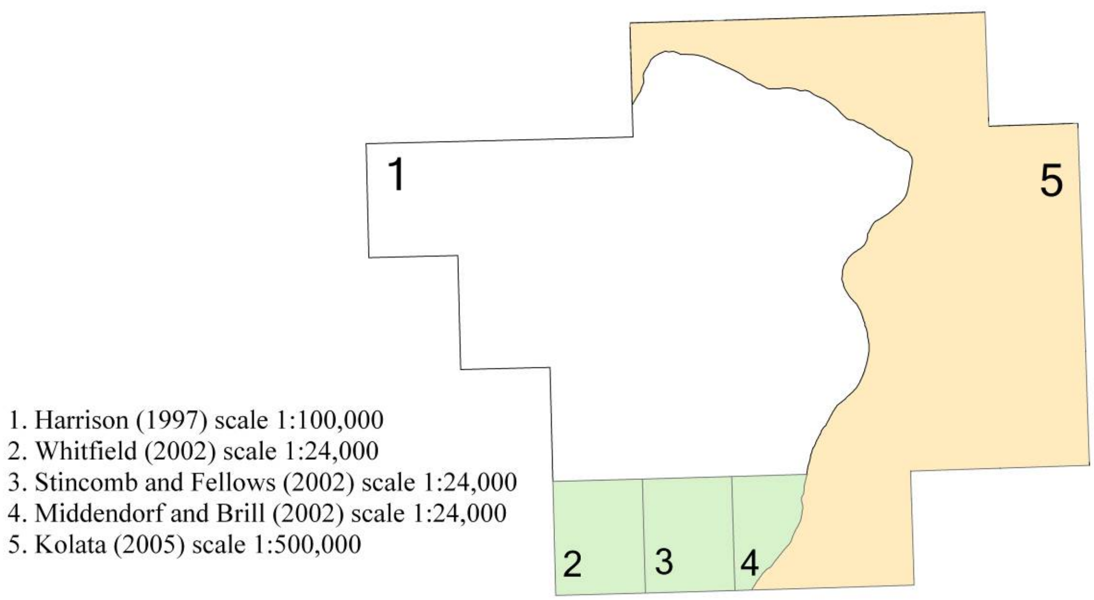

Figure 4. Data sources (5) for bedrock geologic map of the St. Louis metropolitan area.

Table 2. Stratigraphic correlation of recognized of bedrock geologic units and corresponding map symbols in the St. Louis metropolitan area, Missouri and Illinois.

ERA	SYSTEM	SERIES	FORMATION
CENOZOIC	Quaternary	Holocene	Alluvium
			Terrace Deposit
		Pleistocene	
			Unconformity
MESOZOIC	Tertiary	Pliocene	Grover Gravel
		Miocene	
			Unconformity
PALEOZOIC	Pennsylvanian	Missourian	Pleasanton Group
			Modesto Formation/McLeansboro Group
		Desmoneisian	Shelburn-Patoka
			Carbondale
			Marmaton Group
			Cherokee Group
		Atokan	Tradewater
			Unconformity
	Mississippian	Chesterian	Yankeetown Sandstone
			Renault Limestone
			Aux Vases Sandstone
			Ste. Genevieve Limestone
			Lower Pope Group
			Unconformity
		Meramerician	St. Louis Limestone
			Salem

		Warsaw
	Osagean	Keokuk-Burling Limestone
	Kinderhookain	Fern Glen and Bachelor
		Chouteau Limestone
		Unconformity
Devonian	Upper Devonian	Bushberg Sandstone and Glen Park Limestone
Silurian		
		Unconformity
Ordovician	Cincinatian/ Champlainian/Mohawkian	MaQuoketa Shale
		Cape Limestone/Kimmswick Limestone
	Champlainian/Mohawkian	Decorah
	Mohawkian	Plattin Limestone
		Joachim Dolomite
		St. Peter Sandstone

Table 3. Borehole types and items collected in the St., Louis metropolitan area, Missouri and Illinois.

State	Borehole type	# of records	Item
Missouri	Bedrock	2338	Depth to bedrock, Bedrock type
	Corelog	729	Core recovery (%), Rock Quality Designation (RQD)
	Grain Size	93	Grain size analysis of soil
	Material	2330	Description of soil material
	Physical Property	1906	Standard Penetration Test (SPT) N-value, Cone Penetration Test (CPT), ASTM class, Unit weight (water content,%), Liquid limits, and Plastic index
	Water Observation	961	Depth to groundwater

	Site	2394	
Illinois	Highway Log	857	Description of soil material
	Highway Engineering	496	Standard Penetration Test (SPT) N-value
	Highway Head	2226	Description of geotechnical boring
	Log	3636	Description of soil material
	Water Well	4728	Description of water well
	Site	4817	

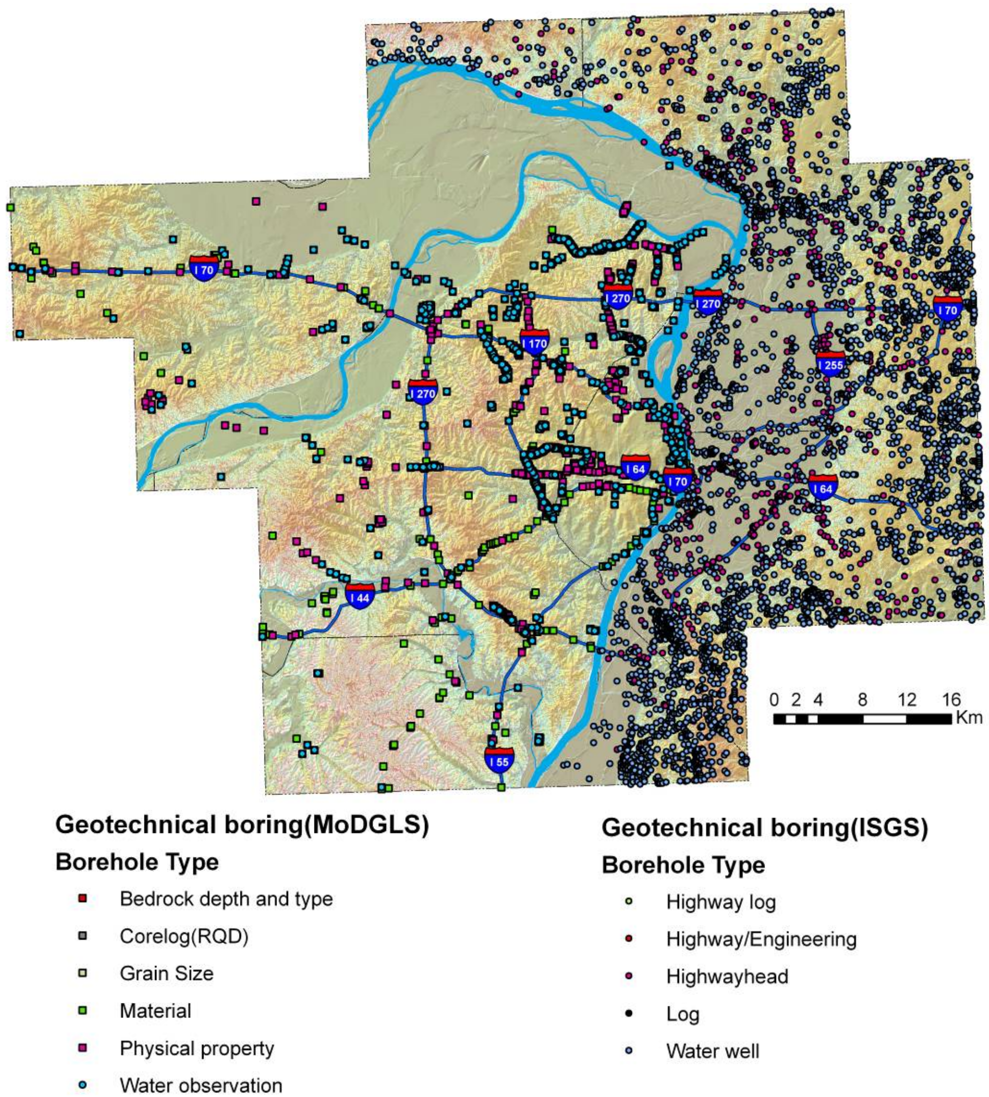

Figure 5. Borehole locations and types in the St., Louis metropolitan area, Missouri and Illinois in a GIS vector format.

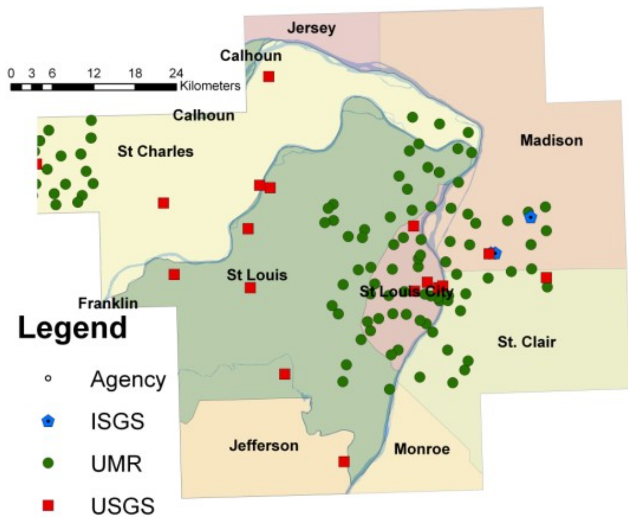

Figure 6. Locations and measuring agencies of shear wave velocity (Vs) measurements

Table 4. The mean shear wave velocity (Vs^{30}) in the upper 30m by surficial geologic unit and corresponding NEHRP soil type.

Surficial Geologic Unit			Vs^{30} (m/s)			
Material	Location	Symbol	Site count	Range	Median	**Mean**
Artificial Fill	along Mississippi River	af(dg)	14	159~620	242	**277**
Alluvium	along streams in St. Charles County	Qa-StC	3	409~454	437	**433**
	along streams in St. Louis County & City	Qa-StL	6	240~456	314	**319**
	along Major Rivers	Qa-MR	10	192~259	230	**228**
	Cahokia fan	c(f)	2	137~254	195	**195**
	Cahokia sandy	c(s)	9	197~264	221	**226**
	Cahokia clayey	c(c)	11	194~304	228	**229**
Terrace	St. Louis	Qld-	5	200~615	347	**360**

or Lake deposits	County & City	StL				
Loess	St. Charles County	Ql-StC	6	410~1123	686	**715**
	St. Louis County & City	Ql-StL	24	182~720	341	**368**
	Illinois	Ql-Il	5	201~386	249	**270**
Till	St. Charles County	Qt-StC	13	293~840	440	**448**
	St. Louis City	Qt-StL	6	218~560	292	**340**
Karst	St. Louis County & City	K	5	410~534	506	**487**